ABSTRACT
              Research in paired-associate overlearning sought
means of decreasing the variability while maintaining the magnitude
of the decrement in stimulus-response latency (SRL). SRL was divided
into decision latency (DL) and manual response latency (MRL); it was
hypothesized that self-pacing of inter-item intervals would reduce V.
Group I received stimuli at fixed intervals after each response group
II controlled the intervals. Practice continued for 16 trials after
the trial of last error (TLE). Self-pacing reduced the variability of
SRL, but also reduced the post-TLE decrement by teaching fast
responses in practice. The task was altered to increase pre-TLE for
group III. Pre-TLE SRL of group III equaled that of group I, but post
TLE did not. Self-pacing slightly reduced the variability of SRL, but
DL was no less variable than SRL, and post-TLE decrement in DL was
less than in SRL. It was concluded that: 1) it was unnecessary to
shape fast responses during practice; 2) self-pacing decreased the
variability of SRL; 3) the attempt to reduce variability by measuring
DL was unsuccessful; and 4) the process underlying post-TLE SRL
decrease influenced both DL and SRL. (PB)

Investigation of Procedures to Control Variability

of Response Latency in Paired-Associate Overlearning*

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Previous research (Judd and Glaser, 1969) investigated response
latency during acquisition and overlearning of a paired-associate task as
a function of training method (a comparison of the anticipation and study-
test paradigms) and of information transmission requirements (eight stimuli
mapped onto two, four, or eight response alternatives). Response latency
during overlearning was found to be sensitive to the effects of the experi-
mental variables, to intra-subject differences in item difficulty, and to
inter-subject differences in learning rate. The data were also consistent
with previous research reported in the literature (Kintsch, 1965; Suppes,
Groen, and Schlag-Rey, 1966) in that latency demonstrated a sharp decrement
during overlearning. These results suggested that the observed decrement
might be indicative of a continued increase in associative strength during
overlearning and might, thus, be useful as a predictor of subsequent
retention. Such a relationship, if it were reliable, would be of interest
as a basis for instructional decisions in computer-assisted instruction.
The accuracy of such prediction would be limited, however, by the extreme
variability of latency measures which had been observed. Therefore, an

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*Presented at the annual meeting of the American Educational
Research Association, New York City, February 4-6, 1971.

attempt was made to determine task conditions which would decrease variability while maintaining the observed decrement.

It was hypothesized that variability would be reduced if the subject were allowed to pace the task himself by determining the length of the inter-item interval. It was anticipated that under these conditions, tne subject, when distracted or reflecting on his previous response, would prolong the inter-item interval rather than pausing after the stimulus was presented. The task which we were using required a motor response and it was further hypothesized that if the subject were given appropriate instructions and preliminary training, the total S-R latency could be divided into two components: a decision period, during which the subject determined which response he was going to make; and a manual response period in which he actually completed his response. It was anticipated that the manual response period would not change systematically over trials but would account for a large portion of the variability in the S-R latency. The decision period would thus reflect systematic changes in latency but would be less variable on an item-to-item basis.

Method

Due to the exploratory nature of the study, the different subject groups involved were run sequentially rather than being randomly assigned to different treatments.

Two groups (designated PALL I and PALL II), each consisting of 16 college-age subjects, were trained by a study test paradigm on a task requiring the association of eight CVC trigrams with eight response keys. Subjects were run on a computer-controlled console designed for paired-associate learning experimentation. Stimuli were presented on a cathode ray tube (CRT)

display and subjects responded by pressing one of eight pushbuttons mounted in a semicircular arc on the response panel. Pilot lamps mounted next to each response key indicated the S-R pairings during study trials. Subjects were instructed to respond with only their index finger and to keep this finger in a "home position" in the center of the pushbutton arc between responses. For PALL I, the home position was marked with a white circle. For PALL II, a ninth pushbutton was mounted in the home position which allowed the subject to control the rate of presentation during test trials.

During study trials, S-R pairs were presented by displaying the CVC and illuminating the appropriate pilot lamp for a period of three seconds. During test trials, stimuli were presented one at a time and remained on the CRT until the subject responded. For PALL I, each item, beginning with the second, was presented 1.5 seconds after the subject's response to the previous item. As an attempt to prevent rehearsal during test trials and to shape fast responding, subjects were instructed that if they did not respond within three seconds of the stimulus presentation, the stimulus would be erased and that item counted as incorrect. This limit was actually enforced only during an immediately preceding warm-up task and no time limit was imposed during the experimental task itself. Subjects were not informed of this change in procedure.

For PALL II, a test stimulus was presented when the subject pressed the home key. Subjects were instructed to keep the home key depressed until they selected a response key and to then press the selected key immediately. They were told that if they did release the home key within two and one-half seconds or did not then press a response key within one second, the stimulus

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would be erased and the item counted as incorrect. Again, these time limits were enforced only during the warm-up task.

PALL II subjects were thus able to determine the duration of the inter-item interval whereas this interval was fixed for PALL I subjects. Since the PALL II subjects were instructed to keep the home key depressed until they selected a response, it was possible to measure their latency of response onset, or Decision latency.

For both groups, practice continued until each of the eight items reached a criterion of six successive errorless trials. The last incorrect response preceding the six errorless trials was designated the Trial of Last Error (TLE) for that item. Practice was terminated ten trials after the last item reached criterion. This assured that each item had at least 16 trials following its TLE. These 16 trials were treated as overlearning and only the date from these trials will be considered. In the table and figures in the handout, all of the response protocols have been aligned on the basis of each item's TLE.

Results--PALL I and PALL II

As shown by the comparison of the S-R standard deviations for PALL I and PALL II in Table 1, self-pacing did reduce the variability of the S-R response during overlearning. Whereas the standard deviation for PALL I, averaged over 16 subjects and 16 trials, was 1544 msec., the comparable value fo. PALL II was only 678 msec. When the standard deviations of individual trials are compared, PALL II is found to have less variable data on 12 of the 16 post-TLE trials.

That these results are not as satisfactory as they first appear is indicated by Figure 1. In addition to reducing variability, the self-pacing

procedure also effectively eliminated the post-TLE decrement which was of basic interest. This basence of decrement was due primarily to the presence of very fast responses during acquisition, as reflected by the lower pre-TLE S-R mean for PALL II. It appears that the two opportunities for aversive feedback during the warm-up task (counting the item as incorrect if the home key was held down too long or if the response key was not pressed soon enough) were too effective in shaping fast responses. Decision latency demonstrated even less of a decrement than did S-R latency. Contrary to expectation, the subjects' manual responses became faster as overlearning drill proceeded.

PALL III Method and Results

In view of these results, an attempt was made to alter the task conditions so as to increase the latency of the pre-TLE S-R responses, and shorten the latency of the manual responses throughout the task, while maintaining the reduced variability demonstrated by PALL II. Consequently, a third group of 16 subjects (designated PALL III(were run on a slightly modified task in which only the instructions and the conditions of the warm-up list were altered from the procedures used for PALL II. No time limit was placed on Decision latency while the time allowed for the manual response was shortened to 0.75 second. Instructions were modified to reflect these changes.

As shown in Figure 2, these modifications resulted in a mean pre-TLE S-R latency which was nearly as great as that of PALL I but the post-TLE decrement was still not as great as that observed for PALL I. As shown in Table 1, self-pacing did reduce the variability of the S-R measure but only slightly--the average standard deviation being 1229 msec. as

opposed to 1544 msec. for PALL I. Comparison of the PALL I and PALL III
standard deviations for individual trials indicates that the beneficial
effects of self-pacing were concentrated in the earlier post-TLE trials.
Self-pacing was apparently actually detrimental during the last few trials.

Decision latency was found to track S-R latency very closely and,
consequently, was no less variable than the S-R measure. The post-TLE
decrement in Decision latency was again less than the S-R decrement. As was
the case for PALL II, the manual responses became faster as a function of
practice.

Conclusions

The attempt to shape fast responding by placing a time limit on
the completed response during the warm-up list appears to be unnecessary
and was detrimental in the PALL II task. The mean pre-TLE latency for
PALL III, in which only the manual response had a time limit, was still
less than that of PALL I.

The self-pacing procedure appears to have some merit for decreasing
variability although not nearly as much as had been anticipated. It is of
interest that self-pacing had a more beneficial effect for the PALL III
group in the earlier post-TLE trials. There are relatively few experimental
or instructional situations which would require 16 trials of overlearning.

The attempt to reduce variability by measuring Decision latency
was not successful. For both PALL II and PALL III, the post-TLE Decision
latency decrement was smaller than the S-R latency decrement. In both cases,
subjects increased the speed of their manual responses during overlearning
and this accounted for some of the decrement observed in the S-R measure.
This tendency was less pronounced for PALL III, but in this case Decision
latency so closely tracked S-R latency that both measures were equally
variable.

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The process underlying the post-TLE latency decrement appears to
influence both the latency of the subject's decision as to which response to
make and the speed of the manual response. It is of some interest to
speculate as to what this may imply. If response latency is a measure of
the time required for some type of retrieval process, one would expect a
reduction in Decision latency as a function of overlearning practice.
However, if one assumes that the subjects followed directions and did not
release the home key until they selected a response key, it is difficult to
explain the observed reduction in manual response latency on the basis of a
faster retrieval time.

If response latency, on the other hand, is at least partially a
function of the subject's confidence in the correctness of his response, the
increased speed of the manual response would appear to be more easily
explained. It is suggested that once a response is selected, the subject
is slower to commit himself to that response if he has relatively little
confidence that it is correct. As overlearning proceeds and the subject
receives additional confirmation, his increased confidence could result in
the observed decrement in manual response latency as well as in decision
latency. This is admittedly a non-parsimonious explanation but it does
receive some support from the area of short-term memory. Murdock (1966,
1968) found high negative correlations between response latencies and
subjects' ratings of their confidence in their responses.

Techniques may be found to reduce the variability of latency
measures without destroying the information which they are assumed to contain
but the authors doubt that any drastic reductions are probable. In

subsequent work concerning the relationship of response latency to retention, the authors have used a self-paced procedure which did not attempt to shape fast responding or to measure Decision latency. On the basis of the preliminary analysis of the data resulting from this research, measures of latency averaged over several trials appear to have some predictive validity. The utility of the latency measures is further enhanced when they are employed in conjunction with correct response probability measures.

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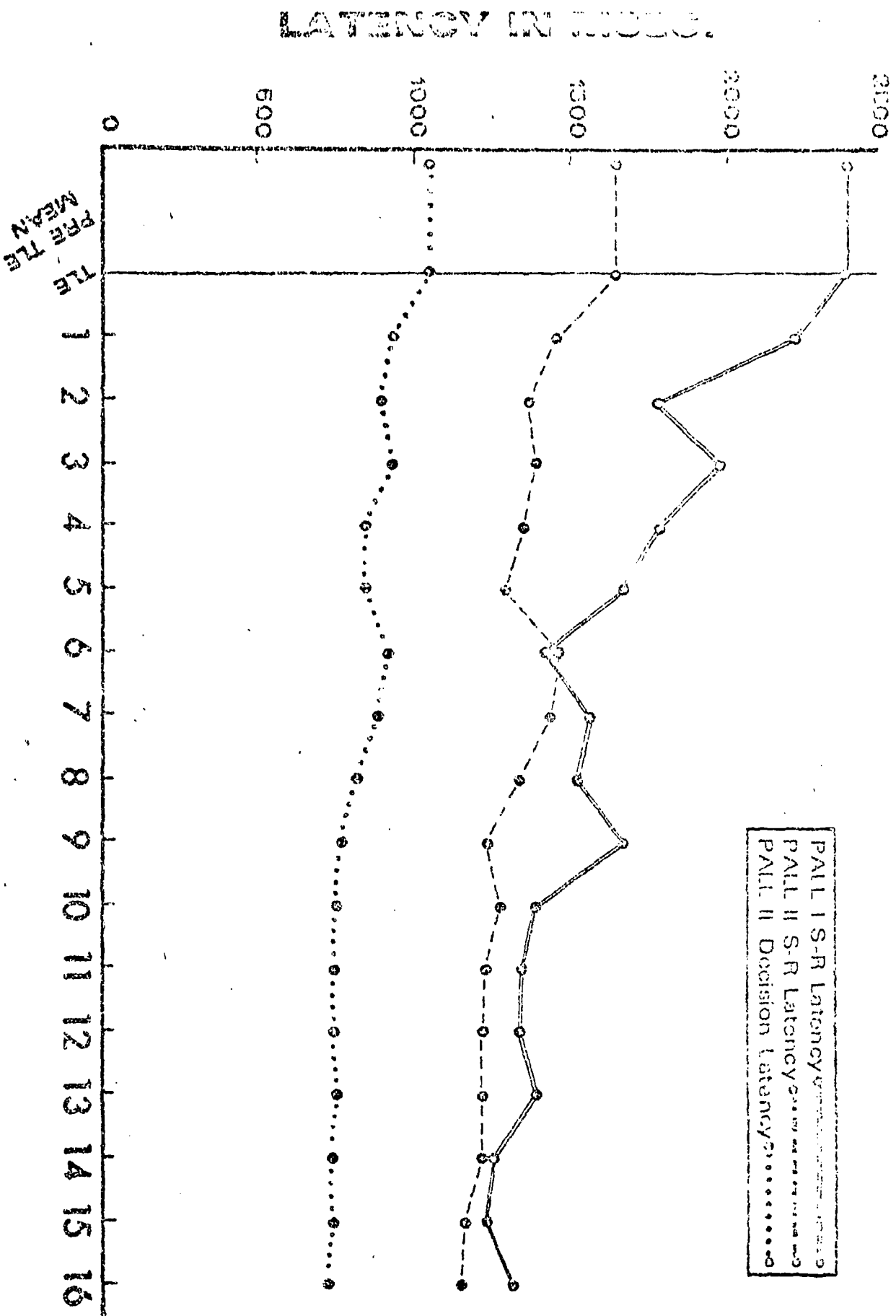
Table 1

Standard Deviations of Response Latencies Obtained under

Three Different Experimental Procedures

(Values shown are means of the 16 Subjects in each group)

| | PALL I | PALL II | | PALL III · | |
	S-R	S-R	DECISION	S-R	DECISION
Trial TLE+1	3178	771	606	1426	1960
TLE+2	1187	501	494	1862	1863
TLE+3	2959	689	545	1988	2002
TLE+4	2286	651	431	1351	1335
TLE+5	1257	541	484	789	772
TLE+6	842	1187	1072	777	775
TLE+7	1119	841	600	1182	1026
TLE+8	928	596	465	1619	1621
TLE+9	1845	498	383	868	862
TLE+10	704	936	379	1064	1034
TLE+11	652	462	427	677	597
TLE+12	753	517	437	896	600
TLE+13	838	482	388	845	849
TLE+14	507	543	381	833	829
TLE+15	465	547	531	1179	1185
TLE+16	1027	477	397	966	969
Post-TLE Average	1544	678	534	1229	1248

LATENCY IN MSEC.

0   500   1000   1500   2000   2500

PRE-TLE MEAN

POST-TLE TRIAL NUMBER

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

PALL I S-R Latency
PALL II S-R Latency
PALL II Decision Latency

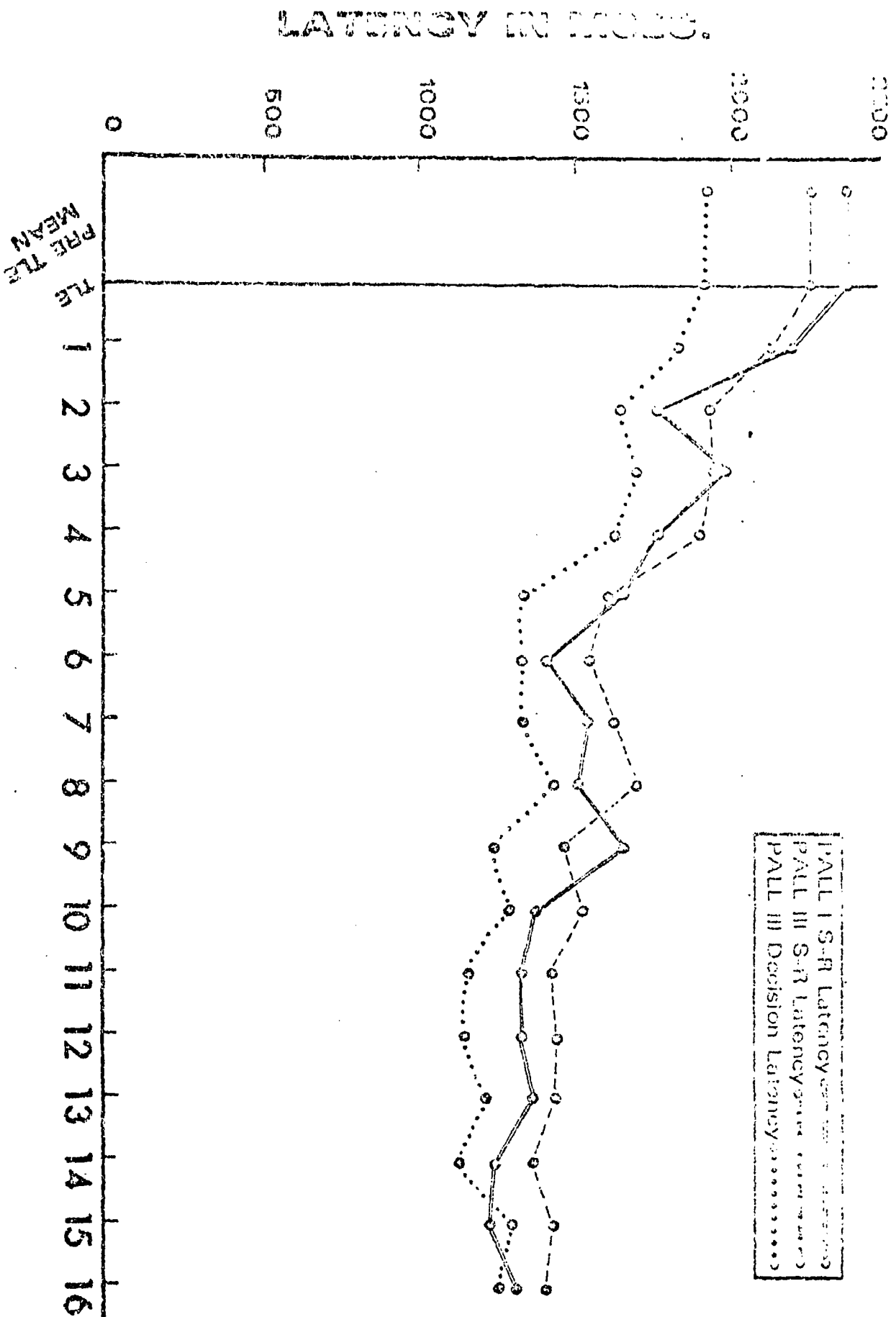Figure 1. Response latencies from the PALL I and II tasks as a func-

Figure 2. Response latencies from the PALL I and III tasks as a function of the post-TLE-relative trial number.